Pilot Study to Establish the Nature and Impact of Effective Undergraduate Research Experiences on Learning, Attitude, and Career Choice

David E. Lopatto, Principal Investigator,
Grinnell College

Elaine Seymour, Co-Principal Investigator,
University of Colorado, Boulder

A. PROJECT SUMMARY

A three-year research project is proposed whose overall goals are to:

- Clarify the nature of authentic undergraduate research experiences—and their variations—in a sample of science disciplines from the viewpoints of participating and non-participating undergraduates (both as seniors and one year from graduation), from faculty, and from their institutions;
- Identify and categorize the essential elements of "good" undergraduate research experiences, the learning gains (cognitive, behavioral, affective, social, and professional) that they produce over time; the conditions and processes by which, these occur; and their relative significance in the achievement of outcomes valued by students and faculty;
- Identify variations in undergraduate research participation, experiences, and outcomes, and the factors that shape them, for women and men; and for white students and students of color.
- Hypothesize and test linkages between aspects of undergraduate research experiences and desired outcomes in the shorter and longer term.

The research design controls for variations in undergraduate research models, institutional contexts, and academic disciplines by limiting the inquiry to one common type of program (mentored summer research for entering seniors requiring a senior thesis, and/or presentation and publication of scholarly work) in a sample of institutions of similar type, with a limited range of science disciplines. Investigation will begin with entering seniors in summer, 2000 programs in four liberal arts colleges with a strong history of engagement in undergraduate research. Methods of sampling and inquiry allow for discovery of variations in the experiences and outcomes reported by female and male participants, by students of color compared with white students, and by female participants in single-sex versus mixed-sex research contexts. Samples will also include two comparison groups of non-participants who either chose not to participate in research programs as undergraduates, or who applied, and were not selected.

Qualitative-with-quantitative methods are employed. A comparative ethnographic exploration of faculty goals and pedagogical methods, and student accounts of their experiences and benefits over time, will ground the development and testing of instruments to assess the impact of undergraduate research opportunities on the education and post-graduate lives of undergraduates. Interview and survey data from the student cohorts will be compared with those from faculty in order to establish, compare, and rank what each group perceives as the benefits of the research experience, and what factors influence their achievement. This part of the project builds upon a preliminary study at one of the participating institutions (Grinnell College). Interviews with students who do, and do not, participate in undergraduate research, with faculty research mentors, and with engaged senior faculty and administrators will be conducted in real time. Alumni who do, and do not, participate in undergraduate research will be interviewed one year after graduation to discern longer-term effects.

Pilot study findings will also provide a research base for the design of comparable, cross-program evaluation strategies for common models of undergraduate research. Instruments developed for use with students and faculty will be refined by cross-validation within the four participating institutions. They will also be refined, and disseminated for adaptation in discussion with faculty in a wider array of institutions engaged in undergraduate research. Findings and instruments will be disseminated for use by colleagues interested in the development of evaluation strategies for undergraduate research projects through a workshop, presentations targeted to relevant audiences, selected web-sites, and published work.

This proposal is set within Quadrant 3 of the ROLE program: "Research on SMET learning in formal and informal educational settings." It is also well situated in Quadrant 2, "Fundamental research on behavioral, cognitive, affective and social aspects of human learning", and offers well grounded information at the intersection of these two areas. The proposal includes several common themes outlined in the program solicitation: qualitative-with-quantitative research methods, cross-disciplinary and multi-institutional collaborations, computer-assisted ethnographic analyses of textual data sets, and use of fundamental research in learning processes and outcomes to inform the development of well-grounded instruments for wider use by faculty, higher education institutions, and others.

C. PROJECT DESCRIPTION

Project Rationale

Our fundamental reason for proposing a basic research study at this time is that, notwithstanding**:**

- a high (and growing) level of interest in undergraduate research,
- the large number of existing programs (reflecting several different models of activity),
- their support both by institutional policies, and by funding from private and public agencies,

examples of well-designed program evaluations are rare, and research findings upon which sound evaluation strategies might be grounded, even rarer. From a sampling of 47 recently published articles and reports on undergraduate research offered to students in a variety of forms and contexts, we developed the following typology of published work according to its purpose (research or evaluation), and the completeness and quality of the evidence offered in support of hypothesized benefits:

Category 1. Five well-designed evaluations with complete information on the methods used.[1-5] They include the only two studies we have encountered that explore the impact of a particular program model upon students of color.[1-2] It is notable that three of these well-designed and well-documented evaluations were conducted by researchers at the LEAD Center, University of Wisconsin-Madison.[1,3,4]

Category 2. Seven evaluations with incomplete descriptions of their methods, and/or design limitations.[6-12]

Category 3. Seventeen articles, describing particular faculty-developed, institutional, or cross-institution programs (employing a variety of models) in which accounts of evaluation methods are missing, incomplete, or problematic.[13-29] This is not a complete list, but samples the largest body of published work on undergraduate research. In their most common form, faculty describe their programs, experiences, participant and/or alumni feedback, and the inferences they draw from them.

Category 4. Ten "promotional" articles in which no evaluation or research evidence is offered,[30-39] that describe the perceived merits of undergraduate research in general, or of particular models of activity, and/or the principles and methods by which to install them;

Category 5. Two review articles that reference evaluation studies, but with incomplete or problematic accounts of methods.[6,40]

Category 6. Two articles that recount the history of undergraduate research with limited reference to research or evaluation.[41-42]

Category 7. Four student-authored accounts of their undergraduate research experiences without reference to research or evaluation.[43-46]

Category 8. One journal article describing the methods and findings of a research study that explored a single, arguably very important, aspect of undergraduate research—changes in participants' understanding of the nature and development of scientific knowledge.[47]

We also note that all but three of the sampled articles and reports referenced undergraduate research in the sciences (including mathematics and engineering), although we are aware that programs are also offered in the humanities, social sciences, education, and professional education,[22] such as nursing,[33] and business.[11] The tradition seems, however, to be strongest in the sciences.

The preponderance of program descriptions, explication of models, and evaluation efforts, rather than research studies in this field is, perhaps, not surprising. As is common for alternative educational strategies, those who develop them are motivated to promote their ideas and experiments and to argue their value and efficacy largely from direct personal experience. It is also understandable that many evaluation components of reports have methodological limitations. Faculty innovators often work alone or in informal groups, with limited funding, access to evaluation expertise, or knowledge of how to monitor their classroom work in a scholarly fashion. There are, however, ironies in this situation, given their common goal of seeking to build research skills in undergraduates. The cross-disciplinary objectives of some initiatives might also (logically) prompt requests for help from colleagues with the requisite skills. Many writers simply omit the details of their evaluation design and methods of data gathering or analysis (particularly where qualitative data are gathered); others offer findings on the basis of samples that are inadequately structured, very small, or reflect low response rates. Work that is otherwise thoughtful in seeking to distill the benefits and difficulties of students' research experiences may also be undermined by sampling biases. For example, in Mabrouk and Peter's[6] recent account, the sample was doubly biased: the authors asked faculty known to them for their own (or their institution's) participation in undergraduate research to identify past and present students who could be contacted as potential sample members. Schowen's[40] finding that at least 75% of the 216 REU students who participated in the University of Kansas research programs since 1988 go on to advanced study in the chemical sciences is compromised because REU participants are specifically those who have professed an interest in chemistry, are entering a chemistry program, and are, thus, predisposed to go on to graduate school. Schowen does, however use a control group ("majors in general, including those who do not participate in research"): most evaluation accounts do not mention comparison or control groups.

Particularly in individual faculty accounts of their work with undergraduate researchers, the problem of small sample size and sample groups that are self-selected, faculty-recruited, or predisposed by program selection criteria to achieve in predictable ways and display expected gains is inherent to the population under study. This makes faculty self-monitoring difficult. In the proposed study, we shall draw samples adequate for generalization, balanced across four participating institutions by discipline, year in school, and gender, and will include samples from two comparison groups of non-participants who either chose not to participate in research programs as undergraduates, or who applied, but were not selected.

Some institutions with a tradition of commitment to undergraduate research have sought to demonstrate the value-added by their approach to undergraduate education using institutional data, most commonly to demonstrate the numbers of former undergraduate researchers choosing graduate school or high-level professional careers.[1,3,4,5,6,7,9,10,11,18,22,26,27,28,31,32,39,40,41,43,45,46] The difficulties with this approach are: lack of evidence for a causal link between undergraduate research experiences and particular career choices, student samples that are self-selected and/or faculty-selected for their propensity to high aspirations, and lack of research data, either on the nature of student researchers' experiences over time, or their processes of career choice development.

These difficulties reflect a "black box" between goals and activities on the one hand, and the outcomes claimed for them on the other. They point to the need for research that:

- grounds both the tacit and articulated hypotheses of faculty practitioners (and their institutions) that have grown out of their experience of developing various forms of undergraduate research used as pedagogy, and
- investigates the nature and strength of linkages between student experiences and the benefits claimed for them.

Both the National Science Foundation and the Council of Undergraduate Research have called for studies that offer a critical analysis of undergraduate research and that may validate its place in the science curriculum.[49,50]

However, the existing body of work does offer the researcher one valuable resource: the literature in all eight categories of our typology includes descriptions of particular benefits--to students (more occasionally, to faculty), to "science," or the wider community--that are hypothesized to be gained through undergraduate research experiences of various kinds. As our typology suggests, these statements may be categorized as "both claimed and well-supported," "claimed, but not adequately demonstrated," and "simply stated." Although most claims cannot, as yet, be validated, they are, nevertheless, of great collective value in the development of protocols for interview-based inquiry, and for reference in the development of instruments designed to test the strength of particular claims. We have begun to drawn upon them for these purposes in developing the research design described for the proposed study. Hypothesized benefits are of different orders; some are very broad; some are very specific. We have grouped those that are most commonly mentioned below, and have couched them in terms of benefits to students. It should

be noted, however, that project descriptions often cite as primary beneficiaries of undergraduate research: their disciplines and professional fields, faculty researchers and their institutions (especially in schools without a graduate program), science as an enterprise, and science literacy as a national resource.

Student Benefits:

- Increased interest in the discipline[1,3,4,5,9,15,18,19,20,22,23,24,26,27,33,34,35,36,38,39,42,43]; increased persistence[1,2,13,20,32];
- Increased understanding of: the research process,[1,3,4,5,7,10,14,24,28,32] how scientists think,[1,3,4,5,13] how scientists work on real problems,[7,8,10,11,13,14,20,22,23,24,26,27,28,30,32,33,39,42] how scientific knowledge is built[47];
- Gains in critical thinking and approaches to research problems,[6,10,13,19,20,32,35,41,43,44,45,46] knowledge,[10,36] and science literacy[3,4,18,20,27,32,34,39,40,41];
- Becoming part of a learning community[1,2,3,8,11,13,15,27,30,42] (especially for students of color)[1,2,3,13]; bonding with faculty (and, thereby, the discipline/career path)[2,3,4,7,8,11,19,20,27,33,39,42];
- Increased self-confidence in ability to do research,[1,3,4,6,10,13,17,32,33,43,45] and self-esteem[11,33];
- Increased skills: research and lab techniques,[1,3,4,5,6,7,10,13,14,31] working collaboratively,[6,7,10,14,15,19,20,35] communication (writing, presentation, argument)[6,7,13,14,19,20,22,23,31,32,35] and leadership[6,7,10];
- Improved approach to learning: shift from passive to active learners[13,17,19,34,35,40,41,42];
- Clarification, confirmation, or choice of a career path (including graduate school)[1,3,4,5,6,7,9,10,11,18,22,26,27,28,31,32,39,40,41,43,45,46]; engagement of students of color (in the sciences)[1,3,9,14];
- Enhanced career preparation: greater readiness for more demanding research and for professional careers in the sciences, [1,3,4,5,9,11,14,18,20,27,32,34,39,41,44,46] professional socialization,[14,19,33] and opportunities for networking.[6,11]

Many of these hypothesized benefits target majors, potential majors, or potential graduate students. More rarely (e.g., Bunnett[36]), authors argue that all students who participate will benefit, not only those who plan a research career. The citations shown above give some indication of the relative frequency with which particular benefits are mentioned. What is surprising is that references to students' increased understanding of the nature of scientific knowledge, and how it is created, refined and challenged are found in relatively few accounts. A notable exception is Ryder, Leach and Driver's[47] ethnography exploring changes over five to eight months in students' understanding of how the validity of knowledge claims are evaluated, and of the role of theory in shaping research questions. The limitation of this otherwise very useful study are its small sample (N=11) and the difficulties of comparability arising from its context—senior projects in science degree courses at a British University. The only report from a Category 1 US study that has investigated learning gains as a result of undergraduate research experience is Fortenberry's[5] finding that "substantive knowledge of the field " was not gained. References to the development of "critical thinking" and thinking about research problems "like scientists," are often vague. We also we found no descriptions of how faculty use the contact time with their student researchers to deepen the "understanding" or "thinking" that they hope to see as an outcome of undergraduate research experiences. Two articles discuss the significance of student-faculty interaction as the main vehicle for the transmission of aspects of professional socialization[1,33] but descriptions of how desired student attributes are encouraged are otherwise missing. As part of our research design, we shall seek to clarify what types of learning gains are made, and how faculty mentors actually seek to develop them in their research apprentices.

We will also draw upon preliminary data from faculty research mentors about the benefits of student research that overlap those listed above. In the summer of 1999, David Lopatto, in cooperation with faculty at Grinnell College, Harvey Mudd College, and Wellesley College polled research mentors in the science divisions of each school and asked them to answer two questions about the benefits and essential features of the undergraduate research experience. Although individual responses were variable, the patterns of responses across the three institutions were similar. The benefits of undergraduate research for students cited by these faculty fit roughly into three categories:

- learning gains: conducting literature reviews, designing and conducting experiments, learning to analyze data
- communication gains: developing skills in written and oral presentation of research
- personal or professional gains: establishing a mentoring relationship, interacting with peers, learning to work independently, clarifying career goals

Descriptions of the essential features of the research experience fell into the same categories, reflecting the kinds of support needed to achieve these benefits.

Alongside important questions about what students gain from undergraduate research experiences, and how they gain them, lies the parallel issue of what is "lost" (if anything) by students who do not participate, and with what

consequences—including their career choices and performance. Only Mabrouk and Peters[6] discuss this. A related question is, by what processes do some students become participants, and others not (i.e., in institutions or departments where participation is voluntary)? Only Kurland[31] considers how to resolve the problem of giving research experience to students who will need it (e.g., for work in industry), but who fail to get it because they are not on a "graduate school track." Four accounts mention the means by which students in schools and departments where participation is voluntary learn about research opportunities. Those noted in published work are by: direct mailing, advertisements in class or residence halls, and orientations to the institution[2]; direct approach to individual students by the program director or faculty[1,6]; student-initiated inquiries within their department[6,19]; and learning about an opportunity via a friend.[6] It is important to discover how students learn about research opportunities, and how well particular advertising systems operate from the students' perspectives. Assuming students are aware of the research opportunities open to them, and apply, there is the further question of how they are selected, especially where competition for places is limited. The only five accounts that discuss the selection process describe highly competitive situations where: nomination is by a faculty member, advisor, or dean, and choice is based on "academic excellence"[27,28]; applicants are chosen on the basis of their GPA and letters of reference from faculty[11] or are judged according to their performance in class work or prior field experience.[21,25,27]

A limited number of studies discuss students' reasons for wanting to participate in undergraduate research[4,8]; most reported reasons are career-linked rather than educational in nature: for credit, to enhance their resume, or prepare for graduate school or professional careers,[8] and to clarify career interests.[4] A counter claim is made by Mabrouk & Peters[6] who report that students undertake undergraduate research primarily to learn to work independently, rather than to author papers or build a resume. As faculty aspirations for their protegees are clearly wider and less instrumental than many of these accounts suggest, it is important to learn what motivates students to participate—or not to do so.

In all instances of student engagement in undergraduate research, but especially in departments or institutions where participation is a graduation requirement, the chances of faculty achieving their goals—whether for students or other beneficiaries—will depend on how well the students are matched to particular faculty, projects, and project groups**.** How these matches are accomplished is rarely mentioned in the literature, and then only briefly addressed. The most common method cited is simply by assignment.[4,7,9,11,14,17,19,21,28,33] In some instances, students were encouraged to chose and design a project of interest to them that also relates to the broad objectives of the research group they are joining.[13,18,29,31] One program offered a list of "suggested projects" from which students could choose,[27] and two programs described a "mutual selection process," whereby students choose a project of interest, then interview with several faculty "to find a good fit."[1,2] Only one (early) report mentions the importance of a good match between the student, faculty, and research project as a condition for success,[39] while two studies found that a good match strongly influenced student satisfaction with the program overall.[1,5]

We shall seek to address this related set of questions of participation, selection, and matching, both among students who participate in undergraduate research, and also with students who either choose not participate, or who apply for research programs, but are not selected into them.

Finally, given ongoing efforts to increase the participation of women in the sciences that are contemporary with the growth of interest in undergraduate research, it is curious that so little attention has been given to studying the impact of undergraduate programs on female undergraduates, and whether and how women's experiences in such programs vary from those of men in ways that shape their outcomes. Of the (only) four studies that discuss gender effects, two studies are somewhat in contradiction: Showen[40] claims that the numbers of women who participate in the sciences, and who opt for graduate study, is increased by the undergraduate research experience. By contrast, Fortenberry[5] found that the aspiration to enter graduate school among both women and students of color did not change. Mabrouk and Peters[6] argue that women and men differ in the qualities they value in their research advisors, and Alexander et al.[4] hint at problems for women in research groups where men are not perceived as valuing their contributions. It will, therefore, be an integral part of this study to identify some effects of gender (and, where possible, given sampling limitations, of race/ethnicity) on the quality of the undergraduate research experience and its outcomes. These issues are addressed both in the research questions and research design described below.

Learning Theory Relevant to Undergraduate Research

Just as there is a lack of research on the processes and impact of undergraduate research, there is also a lack of well-grounded theory. Theories of science education, thus far, have been developed out of research on the learning

processes of children. In so far as the needs of older students are addressed, theory centers on classroom pedagogy, such as inquiry-based learning. The proposed study may aid in the extension of learning theory to the undergraduate research experience. As a preliminary look at the kind of information that the proposed study might yield, we summarize current theory regarding "how people learn"[51] and draw the analogy to include undergraduate researchers.

Children are active learners whose learning is motivated by a desire for mastery. How they learn is partially determined by what they already know, including the schemes and perspectives they bring to new situations. Children's current level of learning is not a true measure of their potential; rather, each child has a "zone of proximal development," a potential learning level beyond what they currently know. This zone can be estimated by giving a child problems to solve that are beyond her current level of accomplishment. If the child can solve these problems through imitation, then the child is said to have learning potential. Children learn best in a supportive environment that includes expert teachers and modern physical facilities. They learn well in groups, as "a community of learners" involving active learning, and learning from more skilled partners. One important outcome of the learning experience is transfer of training, both to new academic experiences and to everyday life.[51]

What is the analogy to college students involved in undergraduate research? Potentially, college students are active learners who are motivated by a desire for mastery. It may be said that undergraduate researchers are gaining expertise. A feature of this expertise is professional, that is, the experts that the student emulates are researchers and teachers in the field. Career choice is a feature of their motivation. How undergraduates perform is partially determined by what they already know. However, the degree to which a curricular experience informs independent research remains to be studied. Part of the prior experience of the undergraduate research is social; in programs in which research is not required undergraduates are likely to work with a mentor they know and from whom they have learned in the classroom. As with a child, an undergraduate's prior classroom learning may not be the truest measure of their potential. College undergraduates may have a "zone of proximal development" that mentors intuitively assess when they select research assistants. This intuitive judgement may influence the selection of undergraduate researchers at institutions where research is not a required exercise. It may be that student potential is further tested by exposing undergraduate researchers to graduate school-like conditions during the research experience. However, this possible test of potential has not been systematically studied. College students also learn best in a supportive environment that includes faculty mentoring, state-of-the-art instrumentation and modern physical facilities.[52] They may form a community of learners, becoming part of a group of active researchers that includes faculty mentors and more experienced students. An important outcome of their experience is transfer of training, both in the specialized sense of continuing in the professional field, and in the more flexible sense of succeeding in unexpected careers.[36] Thus, applying current learning theory to the undergraduate research experience uncovers deficiencies in current knowledge that the current proposal will begin to address.

Research Questions

The research questions are informed by issues and findings in the literature reviewed above. They include questions for which the existing literature provides little information, partial answers, or untested hypotheses. The questions touch on fundamental research issues about the nature and value of research experiences as perceived by variously-situated participants and non-participants over time, features of their experiences that may transcend disciplines, and some issues of concern to the managers and evaluators of particular programs. Although we anticipate that other questions will emerge in the course of this study, our opening, and inter-connected, sets of questions include the following:

The Elements of a Good Research Experience:

- What constitutes an authentic undergraduate research experience? What are the essential elements of a good research experience? What is their hierarchy of importance?

- Can a taxonomy be constructed of the types of research projects that are typically undertaken with entering seniors? How do projects vary?

- By what processes do undergraduate research experiences promote both learning and professional socialization?

The Benefits for Students:

- What learning occurs over time in the course of a good research experience? (Learning is defined to include behavioral, cognitive, affective and social changes resulting from research experience.)

- What benefits are evident by the conclusion of the experience, later in the student's education, and beyond graduation?

- Are there benefits of authentic research experiences for students that transcend disciplinary boundaries?

- How are career orientation, decision-making, and professional development influenced by participation in undergraduate research?

- What variations are discernable in the experiences and outcomes described by female and male participants, by students of color compared with white students, and by female participants in single-sex versus mixed-sex research contexts?

The Dynamics and Consequences of Selection, "Matching," and Non-Participation:
In institutions and departments where undergraduate research is optional:
- For what reasons do students chose and not chose to participate?
- By what processes are student applicants selected and not selected to participate?
- What are the shorter and longer-term consequences of non-participation?

Across the whole sample of institutions and departments:
- By what processes are students matched with particular research mentors, projects, or project groups?
- What role does the nature of the "match" between student, faculty, and project goals play in the quality and outcome of undergraduate research experiences?

The Dynamics of Faculty Involvement:
- What determines the nature of undergraduate research experiences in each department and institution? What institutional (or other) support sustains these programs?

- What differences are there in the ways in which faculty and undergraduates (participants and non-participants) describe the goals and consequences of undergraduate research engagement? What accounts for these differences? How do they affect the nature of participants' experiences and levels of gain?

- What does research undertaken with undergraduates contribute to faculty scholarship and professional development? How is research undertaken with undergraduates evaluated by disciplinary and departmental colleagues with respect to professional recognition and rewards?

The over-arching issues that inform all of these questions are: what does undergraduate research contribute to the education, career choices, and professional development of those students who participate in it; under what conditions are these outcomes realized; and what (if anything) is lost for those who do not participate? It is unlikely that we shall be able to provide full answers to all of these questions. However, we hope to provide sufficient answers to basic questions of definition, classification, measurement, understanding of process, and documentation of gains over time, upon which a framework can be built for an inquiry that encompasses a wider array of institutional types and program models. This will require the development of instruments, and other methods of inquiry, with sufficient flexibility for cross-institutional data collection and analysis in order to plan a more extensive study, and for more immediate adaptation by other researchers and evaluators.

Research Focus and Choice of Study Sites
Models of Undergraduate Research
Our survey of literature reveals three main models for undergraduate research, plus some variations. The primary goal for each model defines the timing and character of students' experiences.

1. *Retention Model:* The goal is persistence in the major through to graduation among all undergraduates in (largely) science disciplines, and/or women and students of color who are under-represented in those majors.

As most field-switching occurs before the start of junior year, these programs target freshmen and sophomores. Among Category 1 studies, both Alexander et al.,[1] and Nagda et al.,[2] report success for the programs evaluated in terms of increasing retention rates, though not significantly so for students of color.[5] Other accounts of programs focused on retention include those by Humphreys,[9] Chaplin et.al.,[13] Manduca,[18] Nikolova,[20] and Strassburger.[32]

2. *Career Promotion Model*: The overall goal is recruitment—more rarely into science majors by offering research experiences to high school students,[32,48] more commonly, into graduate school and careers in the sciences[1,3,5, 6, 8,9, 10,11,14,18,27, 28, 30,31,32,33,40]—through programs that, most often, start the summer after junior year. Increasing the recruitment of under-represented groups is a less often stated goal.[1, 3,9,40] One of the few programs specifically designed for students of color (continued into the first year of graduate school) is that at Rice University.[1] The numbers of undergraduates who choose, or confirm a pre-existing choice of, a career in the sciences (including graduate school) as an outcome of their undergraduate research experience is a commonly-stated goal, although its achievement has been demonstrated only in two published accounts.[1,5] Program descriptions stress developing or confirming student interest in the discipline,[10,18,39,41] professional orientation and preparation.[6,8, 10,18,39,41]

3. *Undergraduate Education Enhancement Model:* The dominant goal for this model is enhancement of undergraduate education by integrating aspects of research experiences into the curriculum. How this is approached, however, varies. In its most common form, research "apprenticeships" (including both summer and all-year participation) are offered largely (though not exclusively) to juniors or seniors, and faculty mentor single students or small groups.[1,2,3,4,5,9,13,14,15,18,19,21,22,26,27,28,29,33,34,35,36,42,47] These programs often lead to a senior thesis and/or presentation at professional meetings and publication with the faculty researcher. A less common variant, "research-based learning" [20] involves pedagogical changes that incorporate research-like experiences into the classroom throughout, or at any time during, undergraduate education.[4,14,17,19,20,21,22,26, 38,35,40] Goals for both include, increasing interest in science[1,4,5,9,15,18,19,20,23,24,26,35,38,39] for all students,[30] understanding the nature of science and of scientific knowledge, processes and methods, [26,28,30,33,34,35,36,37,39] development of scientific reasoning, and active, direct learning of what scientists do.[6,7,8,10,11,13,14,23,24,26,27,28, 29,30,32,33,34,35,39,41,42] A third program variant stresses professional development to improve the capacity of faculty to achieve the goals they aspire to in integrating research into their pedagogy. [8,11,13,38]

Although all the undergraduate research programs surveyed in published work reflect these three models, many are hybrids that include elements from two or more models. In the interests of a coherent research design with limited variance, we cannot address more than one type of undergraduate research model in more than one type of institution. We have, therefore, chosen to focus on summer research apprenticeships for entering seniors that include the production of publishable scholarly work as an important outcome. There are a number of reasons for this choice:

- Summer apprenticeships are the single most common type of undergraduate research experience. Although they combine elements of both career promotion and education enhancement, they are, nevertheless, more homogenous than other hybrid models, which makes cross-disciplinary and cross-institutional comparisons more feasible.
- Student outcome data already exist for this type of program in a number of institutions, including retention and graduation data, and rates of student transfer to graduate school. This also increases the options for cross-institutional comparison.

Although institutions of different type offer summer research apprenticeships, the liberal arts colleges and universities have an especially strong and long-standing collective experience with programs of this type. Some of these institutions (or departments within them) require all students to seek research apprenticeships with faculty; some require a senior thesis based on original work supervised by a faculty mentor or collaborator. Undergraduate research experiences are also seen as contributing to the strong record of liberal arts institutions in sending a disproportionately high fraction of their undergraduates (especially in the sciences) to graduate school. For all of these reasons, it seems important to:

- Understand the processes by which this common, well-established model of undergraduate research contributes to the outcomes sought for it;

- Offer a research basis for the development of appropriate evaluation strategies for types of program and student experience that comprise this model of undergraduate research.

On-site, exploratory research requires institutional support to secure the participation of students, faculty, and administrators, and to gain an appropriate level of access to student records. We have, therefore, selected four liberal arts institutions for this pilot study that:

- Have a strong history of apprentice-style undergraduate research requiring a senior thesis and/or scholarly presentation or publication;
- Have gathered a body of institutional data on student outcomes;
- Are committed to evaluation of their undergraduate research programs;
- Have offered practical support to enable this pilot project on their campuses.

Four institutional sites that meet these criteria, have agreed to take part in this study, and have contributed to the development of the research design are:

1. Grinnell College, Iowa
2. Hope College, Western Michigan
3. Harvey Mudd College, California
4. Wellesley College, Massachusetts.

This set of institutions has additional advantages in that:

- One institution (Harvey Mudd College) requires their undergraduates to undertake research, as does one department (Chemistry at Grinnell College) within a college where participation is otherwise voluntary;
- One institution (Wellesley College) is, historically, an all-women's college
- All four institutions offer summer research programs in three 'core' sciences—physics, chemistry, and biology—with two to four additional opportunities in the sciences, mathematics, engineering, and psychology.

These commonalities and variations allow opportunities for comparison and contrast:

- Between student and faculty experiences in required and non-required research programs
- In student selection processes, and in procedures that 'match' students, faculty, and projects;
- Between the experience for female students in single-sex and mixed-sex research contexts;
- In experiences across the same three science disciplines, and between this common core of disciplines and those in engineering, mathematics, and other sciences, including psychology.

In order not to miss the opportunity to collect data from students and faculty in this summer's undergraduate research programs, each of these institutions has offered to meet the costs of the first round of data collection, beginning in July, 2000. Although this activity precedes the requested start date for this proposal, it is included in the research design (described below) though not in the proposal budget.

Research Design

The research process proposed for this pilot study contains both qualitative and quantitative methods. As some reviewers may be less familiar with qualitative research methods than with surveys and statistical analyses, the qualitative methods proposed are delineated in some detail in the following sections.

Qualitative Research Design

The qualitative parts of the inquiry are designed to explore issues in depth and over time that are not accessible by survey instruments alone. They also provide the information upon which well-grounded measurement instruments will be developed. The qualitative inquiry will be continuous throughout the three years of the study. It will explore both issues of definition and issues of process by:

1. Interviewing two sample cohorts of senior undergraduate researchers on each of four campuses over time, including one year beyond graduation;

2. Documenting (and comparing the degree of congruence between) the perspectives of three campus groups: participating seniors, their faculty research mentors, and senior faculty associated with the undergraduate research program in departments or campus-wide. Interviews will focus upon:
   - the nature, purposes, and value of the undergraduate research program to students, to faculty, and to each institution;
   - the extent of shorter and longer-term student gains attributable to their research experiences;
   - the processes by which these are achieved;
   - the impact on participants' career decisions and on their early career experiences.

3. On the three campuses (and in departments) where participation in undergraduate research is optional, exploring in real time: the processes whereby students decide whether to apply to a summer research program; how they are selected to take part; and the consequences in the short and longer term of not participating for those students who do not apply, or are not chosen. (Non-participants will serve as the comparative group);

4. For all four campuses, exploring in real time the process whereby student researchers become partnered with particular faculty researchers, projects, or project groups;

5. Providing detailed information from the analysis of interview data for each sample of participants and non-participants, and for important subsets of the student sample (i.e., by institution, discipline, sex, and ethnicity).

Theoretical Basis for the Qualitative Research Methods

The methods of data collection and analysis used for the qualitative parts of the project are ethnographic. They are rooted in the methodological traditions common to sociology, anthropology and social psychology, and in the theoretical work of the phenomenologists[53] and symbolic interactionists.[54,55,56] Classically, qualitative studies such as ethnographies precede social survey or experimental work—particularly in fields where existing knowledge is limited—because they are able to uncover and explore issues important to informants, factors shaping their thinking and actions, and estimate their relative significance. The ethnographer generates hypotheses for the positivist to test and questions for the survey investigator to ask. However, since the advent of computer-assistance for the analysis of text data,[57] ethnographers have also been able to disentangle the patterns in much larger text data sets than was previously possible, and to report their findings by the use of descriptive statistics. Although the conditions for statistical significance are rarely met, the results from analysis of text data gathered by careful sampling and consistency in data coding can be very powerful.[58,59]

Sample Structure and Data Collection

Two cohorts of senior undergraduates will be tracked over time across the four participating campuses. Cohort 1 will be interviewed on-site (individually or by research-group) and individually by telephone one year after graduation. Most of Cohort 2 (2A) will be surveyed, but one sub-set (2B) will be interviewed live, as explained below. The qualitative interview samples are intentional samples: the survey samples are structured random samples.

Taken together, the two cohorts include three sub-sets whose membership is determined by their relationship to the summer research programs:

1. Participants in the summer programs for 2000 (1A) and 2001 (2A) (all of whom are entering seniors);
2. Non-participants by choice: seniors graduating in spring, 2001 (1B) who chose not to apply for summer research apprenticeships during their undergraduate careers (at those three institutions where participation is voluntary);
3. Non-participants by selection (2B): rising seniors who apply for a summer research apprenticeship in spring, 2001, but whose application is unsuccessful.

Samples will be drawn from the following disciplines, all of which are offering summer research experiences to undergraduates at the four participating institutions: physics, chemistry, biology, mathematics, geology, engineering, and psychology. Summer research experiences are offered in three of these disciplines (physics, chemistry, and biology) at all four institutions. Participants will be selected from these three disciplines at every site, with additional student interviews from one or two other disciplines (as available) at each site. Differences and similarities will be sought across this set of disciplines between research experiences and their outcomes.

Interview samples will be half female and half male on the three mixed-sex campuses, and all-female at Wellesley College. This allows some comparison of the differences made by the gendered context of the research experience for female participants. Interview samples will also include students of color wherever the student populations in these majors make this possible.

Cohort 1: Interview data will be collected from two groups of seniors in these majors who are graduating in May, 2001. The first group (Cohort 1A, "the participants") will be composed of students entering their senior year and participating in summer, 2000 research programs. Twenty live interviews will be conducted with Cohort 1A members on each of the four campuses in late summer, 2000. To discern differences in the experiences of students working alone with a faculty mentor, and those working under a mentor in a small research group, some interviews will be individual, and some will take place as focus groups of two or three students (depending on particular campus configurations). Thus, the number of Cohort 1A students interviewed will be between 30 and 50 per campus and 120 to 200, in total.

The second group (Cohort 1B, "non-participants by choice") will act as one of two comparison groups. Cohort 1B will be seniors who have chosen not to participate in undergraduate research during their undergraduate years on the three campuses (and in departments) where this is an option. Twenty Cohort 1B members matched by major (and, where possible, by gender) to Cohort 1A will be interviewed individually at each of these three campuses shortly before their graduation in spring, 2001 (i.e., a total of 60 interviewees). During the same site visits, Cohort 1A will also be interviewed for a second time to discuss their career plans and the links (if any) between these and their research experiences. All members of Cohort 1A and 1B will be interviewed by telephone one year after graduation.[1] By all of these means, we shall seek to capture perspectives from all Cohort 1 members on the consequences of participation and non-participation in senior summer research programs toward the end of their summer program (1A only), close to graduation (1A and 1B), and as graduate or professional students, or employees (1A and 1B). In a further study, it will be important to collect samples of perspectives from graduates at longer intervals since graduation, and from their employers, and graduate school faculty to determine whether and how those graduates with undergraduate research experience are better prepared for the post-graduate roles into which they subsequently move than those without such experiences.

Cohort 2: Based on emergent findings from the Cohort 1 interview data, a survey instrument will be developed for administration at two points in time to a second, much larger student sample (Cohort 2A). However, a second Cohort 2 sample will be interviewed in late spring, 2001. These will be (up to) ten non-participating rising seniors on each of the three sites where participation is optional. This sample will be of the same year in school as Cohort 2A. They will have applied for research apprenticeships for summer, 2001 but not selected. They will be referred to as Cohort 2B. These approximately 30 interviews (depending on the actual numbers of applicants not selected) will take place soon after selection decisions are taken, and during the same site visits as the Cohorts 1A and 1B interviews.

Faculty: A sample of up to 80 faculty will also be drawn: actual numbers will depend on how many student-faculty dyads and small research groups are available on each campus. All faculty supervisors of the members of Cohort 1A will be invited to take part in a longer interview in summer, 2000, and in a shorter interview in spring, 2001. In David Lopatto's preliminary investigation of faculty expectations for their research apprentices (described earlier), faculty were in broad agreement that students should acquire an understanding of the research process, along with particular skills, professional attitudes and modes of working with colleagues. In these interviews, we will seek a detailed understanding of faculty learning objectives and other types of gain expected, or aspired to, for their research apprentices. We also wish to learn by what strategies faculty enable the achievement of the goals that they set for their student researchers. As all members of particular student-faculty dyads and small research groups will be interviewed, this affords the opportunity to discover the degree of fit, and also of divergence, between faculty and students' accounts of gains made as a result of their research experiences. Faculty will be interviewed first in order to clarify particular faculty priorities for their students. Students will initially be asked to describe the benefits of their experiences, without prompting; thereafter, they will be asked to comment on their degree of gain in areas

[1] In order to secure the most complete sample of follow-up telephone interviews, all members of Cohort 1 will be asked to provide the qualitative researcher with up-dated information on e-mail and street addresses, and telephone numbers. They will also be asked to give formal permission to have this information retrieved from institutional or alumni association records, if necessary.

identified in the literature, and those identified by their own faculty mentors. (These expectations will not, however, be ascribed to particular speakers.) Finally, we shall discuss with faculty the intellectual, professional, and career significance of their work with undergraduate researchers, and their estimates of its impact for themselves, their institutions, and their students.

In a second interview in spring, 2001, when the selection and matching processes have recently been completed, the same sample of faculty will be asked to discuss how they "spot" and encourage potential student research partners, how the student selection is made, and how the process of matching students to particular faculty and projects is accomplished. We assume the matching process to be of particular significance in institutions and departments where all undergraduates are required to undertake student-faculty research.

Institutional interviews: A small sample (up to three) of senior faculty, chairs, or administrators with experience of each institution's undergraduate research program will also be interviewed. These will be the first interviews conducted at each site. We shall seek to clarify with this group what their departments and institutions expect both students and faculty to gain from a policy of required or promoted research experience. The institution's relationship with funders of undergraduate research will also be explored.

Findings from the resulting data sets will be of intrinsic value in clarifying the nature and extent of gains to both students and faculty from participation in student-faculty research, the processes shaping the nature and extent of such gains, and the linkages between faculty strategies and their outcomes for students. The findings will also guide the development of survey instruments to be administered to a second cohort of students and to faculty in this study, and, after testing, refinement, and adaptation, for use with a wider array of students, institutions and disciplines.

Interviewing Methods

Interview protocols based on the research questions are in process of being developed**.** They will draw upon David Lopatto's findings from his preliminary study of faculty expectations for participating students, findings in Category 1 evaluation reports, and the benefits hypothesized for both students and faculty outlined in accounts labeled Categories 2,3, 4 and 7. Questions used in student interviews will also be guided by information offered by faculty in prior interviews. Interviews will be conducted in the manner of semi-structured conversations that focus on the interviewees' experiences with their research programs over time and their working collaborations with faculty and other students. Issues from the protocols are explored in an order guided by the natural structure of the discussion: those not spontaneously raised are introduced at convenient points in the conversation. New issues pertinent to the research questions that are raised by discussants are always pursued. Thus, from the outset, the opening set of discussion questions is continuously refined and augmented by the emphases that informants place on the factors that they introduce and discuss. As important themes emerge, they are explored in all subsequent interviews.

Methods of Qualitative Data Analysis

All interviews (single and group) will be tape-recorded and transcribed, with the prior permission of the interviewees. In the case of students, this permission is in writing. These tape-recordings of interviews and focus groups are transcribed *verbatim* into a word-processing program and submitted to *The Ethnograph,*[57] a set of computer programs that allows for the multiple, overlapping, and nested coding of a large volume of transcribed documents to a high degree of complexity. Each line-numbered transcript is searched for information bearing upon the research questions. Information is commonly embedded in speakers' accounts of their experience rather than offered in abstract statements. This allows transcripts to be checked for internal consistency between the opinions or explanations offered by informants, their descriptions of events, and the reflections and feelings these evoke. Lines or segments referencing issues of different type, or perceived importance, are tagged by code names. There are no preconceived codes: each new code name references a discrete idea not previously raised. Because answers to the same question are often not of the same character, or do not cover the same set of issues, codes are never developed on the basis of the questions asked, but always by the nature of the responses given. Information is given both in answers to questions, and in more spontaneously-offered comments, narratives, and illustrations. The emotional emphasis with which some points are made can also be coded in addition to the content of the point. Interviewees often make several points in the same sentence or speech segment: each is separately coded. Groups of codes which cluster around particular themes are given domain names and a branching and inter-connected structure of codes and domains is gradually built into a code book which, at any point in time, represents the state of the analysis.

Frequencies are run for codes across each cohort and faculty/administrator groups, and for important sub-sets (e.g., in the student samples, by discipline, institution, gender, or ethnicity). The frequency counts allow the construction of tables that describe the relative weighting of particular issues. As they are not (by design) drawn from random samples, these numeric representations are not subjected to tests for statistical significance. However, they hypothesize the strength of particular variables and their relationships that may, subsequently, be tested by random sample surveys or other means. The information that will be generated from three sets of interviews with participants, two sets of interviews with non-participants-by-choice, one set of interviews with non-participants-by-selection, two sets of interviews with faculty, and one set with administrators/senior faculty will yield rich, detailed and useful insights into the research questions. Findings from the Cohort 1 interviews will also offer a firm research base for the design of survey instruments to be administered to Cohort 2.

Quantitative Research Design

Instrument development: The first written instruments to be produced will be those that collect information to validate and test the conclusions stemming from the interviews, and also provide a means of assessing student learning. The form of the instruments will be two corresponding surveys (one for faculty and one for students) that require quantitative rating of items relevant to the research experience. These items are derived from the qualitative analysis. The qualitative data analysis will suggest both the number of relevant items and their relative weighting. In the quantitative phase the weighted items become a hypothesis to be tested: Do the items maintain their relative importance when presented as a full survey to a new cohort of respondents?

Validation procedures: By conducting interviews and administering two surveys at each of four institutions, we set up a matrix that permits exploration of within-institution validity and reliability, as well as possible convergence of results across institutions. (Embedded in the matrix are scientific disciplines. We will be sensitive to disciplinary differences although our aim is to find more generalizable information.) The initial validation procedure for instrument development of the student survey will be to reflect the information derived from the interviews of Cohort 1 to the four participating institutions in the form of the survey for Cohort 2A, administered in the second summer of the research project. Our hypothesis is that students in Cohort 2A, experiencing the same programs at the same institutions as the students in Cohort 1A, will confirm the relative importance of benefits discovered in the interviews. At this stage of the analysis, the results of the interviews with Cohort 1 serve as a criterion to which the survey results from Cohort 2A are compared. The survey will instruct student respondents to mark if an item is present and to rank the importance of items in the light of their experiences. Thus, both the qualitative and quantitative analysis will yield a pattern of weighted items. These patterns should be similar.

Reliability will be tested using the test-retest method. Students in Cohort 2A will be surveyed once at the end of their summer research experience and again in the spring of the following year. It is expected that the results of the two surveys will be similar. Statistical techniques such as the Spearman correlation coefficient permit the quantitative analysis of ranks.

The findings from faculty interviews will be used to construct a survey of faculty views and expectations about the research experience. This survey will be offered to the science faculty at the four site institutions in the summer of Year 2. Correspondence between interview results and survey results will be taken to mean that the survey is valid.

The data from four institutions will permit inter-institutional comparison. It is hypothesized that common attributes for the success of undergraduate research programs exist at these four liberal arts colleges. These attributes will be revealed in the ranking of the items in the survey**.** The data may converge on one general model of successful undergraduate research programs. It is possible, however, that differences will emerge in the data across institutions. The extent of the convergence or divergence of data across institutions will be of interest as the research is expanded.

Extension of the Research

In the time frame of the pilot project, we will develop the assessment instrument built on the foundation of findings from the in-depth interviews of students, faculty and administrators. In the short term, we may compare the instrument's results to the interview results, as well as administer the student instrument twice. To this point, there is a criterion variable that is only implied, rather than explicated. That is, by choosing to perform the project at the four initial site institutions, we conclude from the institutional histories (including the AIRE awards) that these four programs are successful. Thus, the pattern of weighted items that define the benefits of these programs become a

model (or models) of successful undergraduate research. The derivation of this model is an end point for pilot work and a starting point for further research. One direction for this extended effort is to cross-validate the model of successful undergraduate research at new research sites. This extension will involve using the survey instrument to evaluate summer undergraduate research programs at colleges and universities that may be willing to participate. A plan for this wider use of the research is presented in the dissemination section.

Concurrent with the proposed research, we will investigate the use of short-term criterion variables that measure student learning. For example, we will explore the use of survey results in the prediction of grades. The weighted items of the survey results become the predictors in a multiple regression analysis of the grade criterion. We expect grades to be a modest criterion variable, however, because the range of grades is likely to be restricted at these site institutions. A more promising criterion may be one based on a cognitive taxonomy of research problems.

A goal of the current project is to produce assessment instruments that are not discipline-specific. One way to visualize this goal is to consider student undergraduate research projects, not by discipline or research topic, but by the cognitive challenge facing the student. We conceptualize scientific research as inherently a problem-solving activity. The task is to identify the type of problem to be solved, and then to assess how well the student solved it. In this way we identify the research experience without depending on the specific discipline. Further, to the degree that the student has identified and solved the problem, we assess how well the student has developed from novice to expert—a learning outcome. To make progress with this concept, we will look at the range of undergraduate research projects undertaken at the site institutions. By inquiring of the faculty who supervise the research, we will be able to identify student projects that are ostensibly similar, despite being situated in different disciplines. Some categories of problem-solving already suggest themselves, such as those related to experimental design. The elaboration of problem categories is one aspect of this part of the project; the other is to find a short series of questions that, when answered, quickly allow the assessor to place the problem in the appropriate category.

Linkages Between the Results and the Questions Posed by the Study

The elements of good research experiences: The research will yield information about the elements of good research experiences. These elements will be identified in the analysis of interview data and validated with survey data. Ranking these items will help identify their hierarchy of importance.

We wish to develop a means of classifying the nature of the student's research experience by asking students and faculty relatively few questions regarding the nature of the scientific problem on which they are working. Guided by their responses to these questions, we hope, eventually, to classify undergraduate research projects according to a taxonomy that does not depend on discipline. We wish to ask essential questions regarding the cognitive challenge or problem-solving involved with the project.

Information received from faculty and students will reveal the variety of interactions between faculty mentors and student researchers that result in learning about, and appreciating, the professional life of scientists. We will review the information by source (e.g., by academic discipline and institution) to find similarities and differences in programs.

Benefits for students: The survey instrument (based on the outcome of student, faculty, and administrator interviews) will capture the benefits of the undergraduate research experience quantitatively by having the students rate the degree to which they attained the benefits suggested in the instrument. The full range of "learning" is taken to include changes from experience in behavior, cognition, affect, and social behavior regarding science. Thus, the interview and survey responses will measure -dimensions of student learning.

The dynamics and consequences of selection and non-participation: We will better understand the fit between selection processes and outcome in the second cohort. The survey data will permit an assessment of the success of selection and faculty-student matching procedures.

The dynamics of faculty involvement: We will compare student and faculty expectations and experiences that are reported in interviews and surveys. We will attempt to quantify the concordance or discrepancy between faculty expectations for the student and the students' expectations for themselves. We will also pose questions that will assess the form of faculty and student interactions.

Management Plan

The PI and Co-PIs will form a steering committee that will meet once or twice per year, and confer regularly by telephone to discuss progress and adjust the direction and pace of work, as needed, to ensure achievement of project goals. David Lopatto and Elaine Seymour will collaborate continuously in the design of protocols and instruments, in drawing samples, implementing aspects of the research design, and discussing emergent findings and their dissemination. They will also submit reports summarizing progress and emergent findings to the group prior to those meetings.

Dissemination

An over-arching goal of this pilot study is to provide well-grounded information that may be drawn upon by faculty and institutions active in undergraduate research in designing their own evaluation strategies. We also see the potential for the development of shared evaluation strategies for groups that are using parallel models of undergraduate research. Both at early stages and near completion of the project, therefore, we need to know the potential utility of our work by discussing emergent findings and instrument design with potential users in the wider community of undergraduate research practitioners.

After two years of the study, therefore, we will co-sponsor a workshop with Project Kaleidoscope at Grinnell College. We will invite approximately 30 faculty and administrators from institutions with strong track records in undergraduate research (including REU grantees) and representatives of funding agencies, several of whom have already indicated support for this project. Lopatto and Seymour will present their findings to date, and the instrument designs this work has generated. They will solicit feedback following small group discussion by participants from like institutions. The Co-PIs and colleagues collaborating on the project will record and summarize these discussions and collect suggestions for instrument revision. This set of institutions will also provide a core sample frame from which we will select instrument test sites during subsequent research. The grant will cover on-site expenses for participants, but the participants' home institutions will be expected to cover their travel costs. James Swartz (Co-PI), who will host the workshop, has extensive experience in organizing faculty development workshops. For the past five years, he has been the Director of the Pew Mid-States Science and Mathematics Consortium, which has organized three to four faculty development workshops annually. He is also co-Chair of the Project Kaleidoscope Facilities Task Force with whom he has worked to organize several facilities' workshops in each of the past four years.

Once we have results from this testing, plus users' observations on implementation, both these and the finished instruments will be offered to the National Institute of Science Education (NISE) for inclusion in the Field-Tested Learning Assessment Guide (FLAG), originally developed by Elaine Seymour for NISE, and maintained and expanded by their College Level One Team. We also plan to disseminate the results of this work by more standard means. Grinnell College will maintain a web-site with up-dates on findings (including annual reports to ROLE). We will also submit papers to appropriate conferences (e.g., CUR) and journals.

Audience

The information generated by this study will be useful to an array of stakeholders in the future of science education. National organizations have been discussing undergraduate research and its impact on students. The American Association of Colleges & Universities (AAC&U), the Council on Undergraduate Research (CUR), the National Conferences on Undergraduate Research (NCUR) and Project Kaleidoscope (PKAL), as well as professional societies, all recognize the importance of research, both to faculty and to undergraduates. Private and public foundations that fund science education include programs that are specifically designed to encourage and enhance undergraduate research activities. Private foundations include the Howard Hughes Medical Institutes, the Beckman Foundation, the Murdock Trust, the Sherman Fairchild Foundation, the Lancy Foundation, the Research Corporation, the W.M. Keck Foundation, the Camille and Henry Dreyfus Foundation, and the Welch Foundation. Significant funding of undergraduate research in science is also provided by the National Science Foundation, the National Institutes of Health, the Department of Education, and other federal agencies. In addition, many academic institutions are members of well-structured and highly active cluster organizations whose purpose is to share institutional strengths in order to enhance programs in member institutions. Such organizations include the Great Lakes College Association, the Associated Colleges of the Midwest, the Pew Mid-States Science and Mathematics Consortium, and the associations of state colleges and universities. Our findings should enable these organizations to better assist member institutions as they consider how to implement and sustain undergraduate research programs appropriate to each educational environment. Many institutions of higher learning proclaim undergraduate research

as a cornerstone of their science program. While this claim may be well justified, most institutions have not yet established a well-articulated evaluation plan to document the nature and extent of their achievements. The outcomes of this study will offer instruments for local adaptation to institutions that are working to design and implement evaluation methods appropriate to their objectives.

Time Line of Activities during the Period of this Study

Year 1	July-Sept., 2000	Interviews with Cohort 1A, faculty and administrators.[2]	Continuous transcription, hand coding, data entry, processing and analysis; codebook development for the qualitative data throughout the grant period.
	Spring, 2001	Second interviews with Cohort 1A and faculty. First interviews with Cohort 1B and Cohort 2B.	Analysis of interview data for use in survey construction.
Year 2	Summer, 2001	Survey Cohort 2A and faculty.	Work with four sites on survey administration. Continued qualitative data analysis throughout year.
Year 3	Summer, 2002	Telephone interviews for Cohorts 1A and 1B as alumni; follow-up surveys for Cohort 2A. Dissemination workshop.	Survey and telephone interviews. Analysis of both data sets. Development of workshop materials.
	Fall, 2002		Preparation of findings for final reports begins
	Spring, 2003		Final reporting and manuscript preparation.

[2] This round of interviews will be funded by the four participating institution, not by the current proposal.

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